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DEVELOPMENT OF AN ELECTROPHORETIC IMAGE DISPLAY

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November 1, 1980 to January 31, 1981

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The purpose of this work is to develop an X-Y addressed electrophoretic image display (EPID). At a recent DARPA/PL/ISI meeting it was agreed to increase the size of the display from 350 x 600 to 360 x 640 elements. Glass substrates with the required In_2O_3 thickness have been obtained commercially; it is now no longer necessary to deposit additional material. Better definition of the row electrodes has been obtained by using this glass and using ion-beam milling rather than liquid etching. Techniques to identify and

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20. ABSTRACT (Cont'd.)

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PREFACE

This work is being performed by Philips Laboratories, a Division of North American Philips Corporation, Briarcliff Manor, New York under the overall supervision of Dr. Barry Singer, Director, Component and Device Research Group. Mr. Richard Liebert, Metallurgist, is the Program Leader; Mr. Joseph Lalak, Electronic Engineer, is responsible for cell fabrication and technology. Mr. Karl Wittig, Electrical Engineer, is responsible for circuit design; Dr. Howard Sorkin, Organic Chemist, is responsible for electrophoretic suspensions.

This program is sponsored by the Defense Advanced Research Projects Agency (DARPA) and was initiated under Contract No. MDA903-79-C-0439. Dr. Robert E. Kahn is the Contracting Officer's Technical Representative for DARPA.

The work described in this sixth Quarterly Technical Report covers the period from 1 November 1980 to 31 January 1981.

SUMMARY

The purpose of this work is to develop an X-Y addressed electrophoretic image display (EPID). At a recent DARPA/PL/ISI meeting it was agreed to increase the size of the display from 350 x 600 to 360 x 640 elements. Glass substrates with the required In_2O_3 thickness have been obtained commercially; it is now no longer necessary to deposit additional material. Better definition of the row electrodes has been obtained by using this glass and using ion-beam milling rather than liquid etching. Techniques to identify and repair shorts in the row electrodes have been developed. The number of defects has been reduced by better filtration and proper outgassing of the photoresist. Aluminum spits were eliminated by using electron-beam evaporation rather than evaporation from a tungsten coil. Sputter deposition of ITO has been replaced by the more reproducible evaporation technique. To obtain better electrical contact between the display and the fan-out board, the homogeneous conductive elastomer was replaced with a laminated one. A device free of shorts or opens in the row electrodes and free of shorts between the column electrodes is now being tested.

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1. INTRODUCTION

Glass substrates with a sufficiently thick In_2O_3 layer have been obtained commercially. Mylar bonding and subsequent ion-beam milling are now routine, and a high yield of usable substrates is being obtained. Techniques to identify and repair shorts early in the fabrication process have been developed; this has improved the yield of good devices. Refinement of photolithographic techniques and increased use of the clean room have resulted in fewer shorts. Sufficient working devices have been available to begin optimization of the suspensions. Work has begun on the Phase II device which will now have 640 columns and 360 rows.

2. FABRICATION TECHNOLOGY

2.1 Fabrication of Row Electrodes

In the past it had been necessary to increase the thickness of the In_2O_3 layer on the purchased glass-substrate material in order to allow for sufficient over-milling of the Mylar; this ensured complete removal of the Mylar and epoxy from the potential wells. A commercial source of glass with In_2O_3 layers about 4500 Å thick, rather than the 1500 Å previously used, has been found. However, the thicker layers contained defects which resulted in intolerable under-etching when a liquid etch was used. This problem has been resolved by using ion-beam milling rather than liquid etching to define the row electrodes. The manufacturer is attempting to supply defect-free material.

Shorts between row electrodes have been a nagging problem, but there has been little problem with open row electrodes. Defects in the photolithographic masks, photoresist debris, and airborne contamination have been responsible for these shorts. The use of better masks, more frequent and more stringent cleaning of the masks, elimination of the photoresist edge bead, the use of a finer filter for the photoresist, better handling techniques,

and increased use of the clean room has resulted in a marked reduction in row electrode shorts. All substrates are 100% inspected after development of the photoresist. If defects are found, repair is attempted by using a fine probe to remove the unwanted resist. After ion-beam milling, the substrates are 100% probed for shorts. If the photoresist repair has been incomplete or the substrate was contaminated during ion-beam milling, shorts will be detected. These shorts are then repaired using a diamond scribe to remove the unwanted In_2O_3. These techniques have resulted in the fabrication of row electrode substrates free of shorts. Substrates with opens are identified during the 100% inspection and are not processed further. Thus, only substrates free of row opens or shorts continue through the process.

2.2 Fabrication of Control Electrodes

Bonding the Mylar dielectric to the row-electrode substrate continues routinely even though the thicker In_2O_3 row electrodes are now used. The reproducibility of the ITO sputtering process was so poor that this process is no longer being used. Thermal evaporation of In_2O_3 onto the Mylar has been found to give low-resistivity transparent layers of consistent quality. This process is now used exclusively for deposition of the column electrodes.

Aluminum is used as the mask during ion beam milling of the potential wells in the Mylar. To facilitate the subsequent removal of this aluminum, a layer of photoresist is deposited on the In_2O_3 prior to aluminum deposition. If all of the volatiles are not removed from this resist, "bubbles" can form under the aluminum during subsequent processing. Baking alone has not resulted in complete removal of volatiles. The sensitizer in the resist is a source of gas, and it must be decomposed prior to aluminum deposition. This has been accomplished by blanket over-exposure before baking.

The problems from spits resulting from evaporation of aluminum from a tungsten coil have been eliminated by using an electron-beam evaporator located in a clean room. Since bubbles and spits have been eliminated, damage to the column-electrode mask has been substantially reduced. The techniques applying to the photolithography on the row electrode have also resulted in a marked reduction of shorts between column electrodes. The repair of shorts in the column electrode is more difficult and less successful than in the case of the row electrodes. This is because the column electrodes are on the relatively soft Mylar surface rather than glass. The mechanical repair methods cause excessive damage to the Mylar. Though it is now possible to make substrates that are free of shorts between the column electrodes, the yield is too low. Alternate repair methods are being considered.

Ion-beam milling of the control electrode continues to produce good results. However, we are experiencing some difficulty in completely removing the aluminum mask after milling. This is believed to be due to the redeposit of material on the walls of the potential wells as they form. This material may be coating the edges of the photoresist beneath the aluminum. Thus, the resist is protected from the solvent during the wash-off operation. The amount of redeposit is affected by the angle-of-incidence of the ion beam. By changing this angle we hope to eliminate this difficulty; in the meantime, the small amount of aluminum remaining will not cause serious problems in device evaluation.

2.3 Suspensions

Previous to this contract, control-electrode cells were made with photoresist as the dielectric and aluminum as the grid electrode; in addition, the size and depth of the potential wells were different. As a result of these changes in materials and geometry, it has been necessary to use different electrophoretic suspensions to obtain optimum performance. We are now

making tests to determine which composition best meets the needs of this device. The brightness of the display is affected by the amounts of pigment and dye used; the size of the pigment particles can be modified by the cleaning procedures used and this affects the optical properties; the type, color, and amount of dye not only affects the optical properties of the display but also the stability of the suspension; the stability is also greatly affected by the type and amount of stabilizer used and this in turn affects the optical properties. In addition, certain suspension compositions can result in pigment adhering permanently in the wells. This condition results in an intolerable reduction in contrast.

A number of operable devices have become available, and experiments to determine the optimum suspension composition have begun.

3. DEVICE TESTING

As the number of shorts and opens have been reduced, devices with modest-size working areas have been tested. The potential difference between the row and column electrodes required to hold the pigment in the wells at full anode voltage has been found to be constant for a given type of suspension. This indicates that the geometry of the devices is reproducible.

The most recent device has row electrodes free of opens or shorts and column electrodes free of shorts. Bubbles in the aluminum have not yet been totally eliminated, and there are a number of column-electrode opens for this reason. The device has three areas greater than 1/4 inch wide which operate properly over the entire 1.5 inch height. We are now attempting to display information on this device with an existing driver. Figure 1 shows a test pattern displayed on the device.

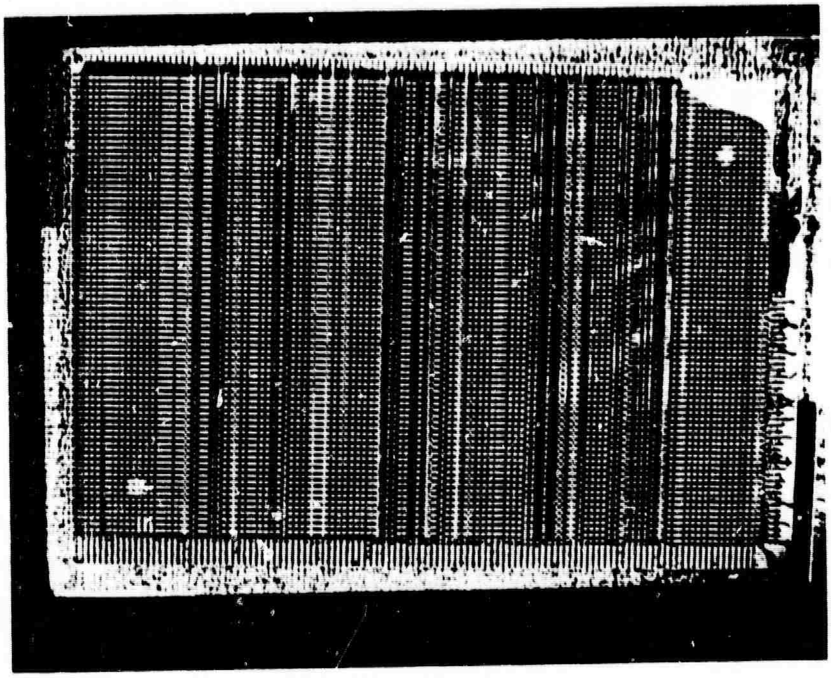

Figure 1: Test pattern shown on Phase I device.

4. DRIVE ELECTRONICS

The elastomeric conductor described in the previous quarterly report has proven difficult to use in this application. Because of the pressure required to establish contact, the conductive area becomes too large, causing shorts between adjacent electrodes. To alleviate this problem we are testing a laminated conductive elastomer. Preliminary tests using the device described in Section 3 indicate that the laminated material is superior to the homogeneous elastomeric conductor.

5. PHASE II

An alignment/exposure system capable of accommodating the larger Phase II substrates has been selected and ordered. Delivery is expected about the third week of March.

Since the semiconductor industry does not require masks greater than 6 inches square and the printed-circuit industry does not require very fine lines, a mask vendor has been difficult to

find. The masks for the Phase II device will require an 8" x 10" mask with 6 μm lines over a 6.4" x 3.6" area. Several vendors having such a capability have been identified. The pattern-generating equipment of these vendors will have to be compatible with the digitizing equipment available to us.

Because a 10" diameter ion-beam miller will be required to fabricate the Phase II device by our present methods and because such a miller is not available to us, we are looking at alternative fabrication methods. We have had experience in the past with photoresist as the dielectric instead of Mylar. Since advances have been recently made in dry-film photoresists which can be laminated to the substrate in reproducible thicknesses, we are re-evaluating our original method. Preliminary tests to determine the compatibility of this new resist with the components of the suspension have begun.

6. PLANS

a. Connect a suitable display to the driver and debug the driver.

b. Demonstrate a working Phase I device.

c. Design and order masks for Phase II device.

d. Continue investigation of alternatives to ion-beam milling.

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